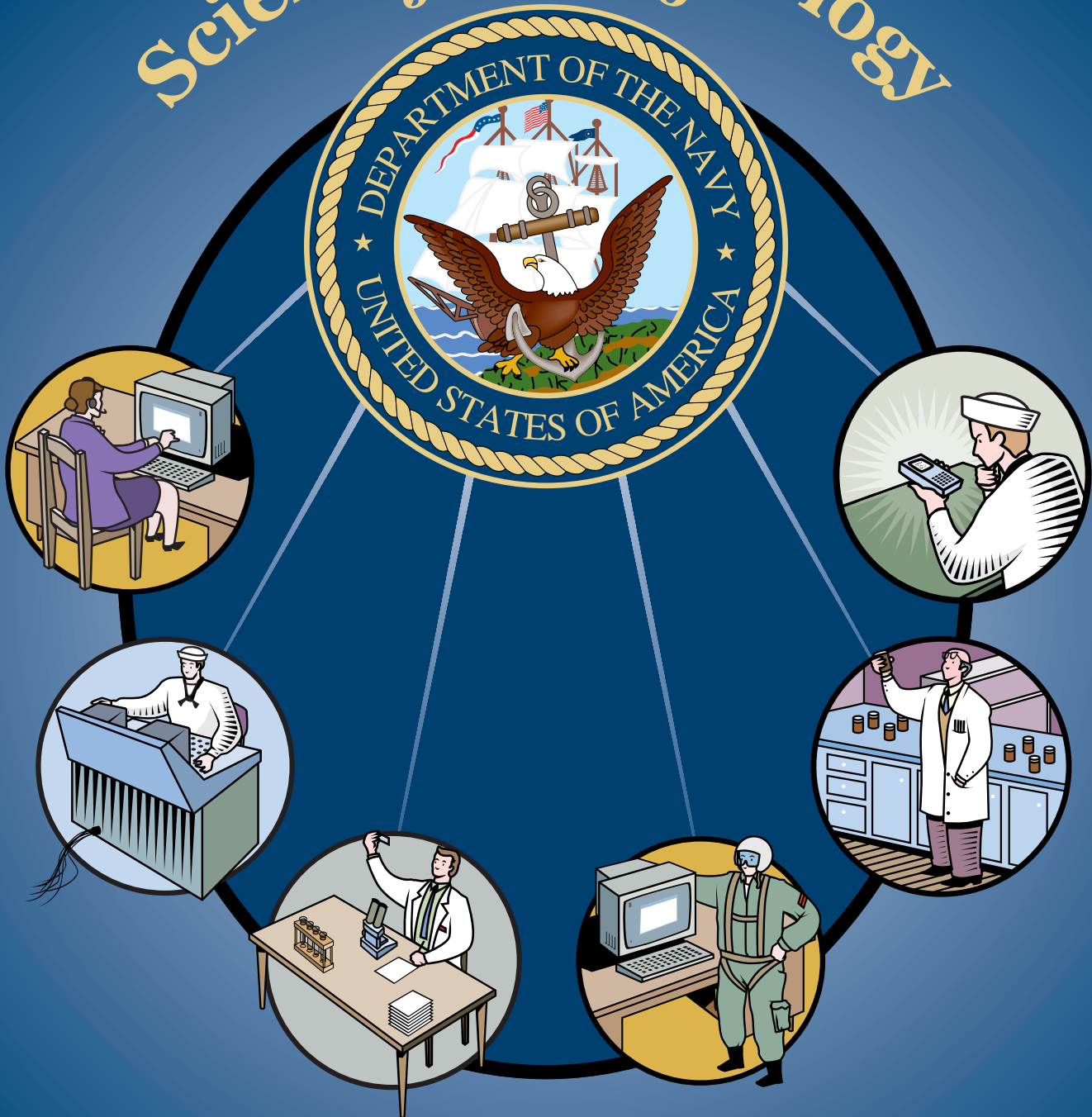




Science & Technology

June 2000



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Naval Research Advisory
Committee Report



Science & Technology
June 2000

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Table of Contents

Report Documentation Page	i
Title Page	iii
Table of Contents	1
Executive Summary	3
Objectives.....	5
Panel Membership	7
Sites Visited	9
List of Briefings	11
Commercial Technologies	15
Technology Trends.....	17
Study Methodology	19
Focus on Europe	21
Take Away.....	23
Telecommunications Overview.....	25
Evolution of Network Performance.....	29
Radio Access Technologies.....	31
Telecommunications Sites Visited.....	33
Opportunities for Collaboration (Telecommunications)	35
Telecommunications Summary	37
Power Electronics Sites Visited.....	39
Power Electronics Overview.....	41
Technology Roadmap	45
Opportunities for Collaboration (Power Electronics)	47
Power Electronics Summary	49
Findings Summary	51
Appendix A. Questions to Commercial Companies.....	A-1
Appendix B. Assessment Methodology	B-1
Appendix C. Terms of Reference.....	C-1
Appendix D. Acronyms	D-1

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Naval Research Advisory Committee Commercial Science and Technology Executive Summary

In early 1999 the Naval Research Advisory Committee (NRAC) was tasked by the Honorable Lee Buchanan, Assistant Secretary of the Navy (Research, Development and Acquisition) [ASN(RDA)], to assess how the Department of the Navy (DON) could leverage commercial science and technology (S&T). In response, an NRAC panel was formed with the following study objectives: to identify how the DON could capitalize on relevant research and development (R&D) produced by international commercial industry; to develop an understanding of the commercial S&T investment strategy; to identify mutually beneficial technology opportunities for the DON S&T community to collaborate with commercial industry; and to propose a DON methodology to assess and utilize relevant technologies.

The sponsors for the study were the DON Chief Technology Officer (CTO) and the Commanding Officer, Office of Naval Research International Field Office (ONRIFO). Because commercial technologies are increasingly global, and based upon the resident technical expertise and collaborative work in progress at the ONRIFO London Office, the study focused on European commercial companies.

Prior to the 1980s, US Government investments drove the technology content of US and world industries. The trend since that time has dramatically shifted to industrial investment. The magnitude of commercial R&D investment is significantly greater than that of the Department of Defense (DoD), and the disparity has been growing for years. This has resulted in significant improvements in commercial product performance and reductions in life cycle costs.

The panel assessed two technology areas that are critical to DON needs and where Europe is a leader: Power Electronics and Wireless Telecommunications. Panel members visited key European industrial leaders in each technology area in December 1999. A prepared list of questions was provided to each company in advance. The panel intent was to develop an understanding of the near term investment strategy and identify opportunities for S&T collaboration. If successful, the panel would determine enough information to comment on the DON's ability to understand and influence these commercial technology investment strategies. The panel felt that by examining two technology areas led by European companies they would (1) highlight the global nature of commercial technology; (2) stimulate similar assessments in the US and Asia; and (3) generate an assessment methodology.

The panel found that the commercial sector has a comprehensive technology plan and a willingness to share it openly. However, the DON's ability to influence commercial technology development is minimal, if at all.

In today's military climate of increasing requirements and decreasing budgets, the DON should adopt commercial products "as is" to keep up with certain technologies and save money. The panel also emphasized that the use of open architectures is essential for effective incorporation of the rapid changes in technology and products. Open architectures will also enable the DON to replace parts and systems with an end result of improved product performance at much lower lifetime cost.

The panel recommended that the ASN(RD&A) drive the adoption of commercial systems and establish a policy for exploiting commercial technology that contains a mechanism for collecting and understanding information on future commercial technology. In addition, the panel felt that DON participation in international standards committees would provide opportunities for interface or, at least, an understanding of the projected outcomes of various options for standards.

The key elements of the recommended panel methodology are to: (1) identify product lines and/or technologies of interest to the DON that are led by the commercial sector; (2) understand those product lines and/or technologies with respect to DON requirements; (3) determine future commercial product stability and development strategy; and (4) incorporate commercial products into the DON investment strategy.



Synopsis of Terms of Reference— Objectives of the Study

- Consider approaches that the DON can employ to capitalize on relevant R&D produced by international commercial industry.
 - Identify examples where European companies lead. Computer, telecommunication and environmental sensor technologies were suggested as examples.
- Develop an understanding of the intermediate-to-long-term S&T investment strategy of the identified industrial sectors.
- Identify mutually beneficial opportunities for DON S&T collaboration in the commercial industrial sectors reviewed.
- Propose a methodology for DON to assess and utilize these technologies.

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Objectives of the Study

In early 1999, based upon a question from the Honorable Dr. H. Lee Buchanan, ASN(RD&A) a committee was tasked, with NRAC support, to study how the DON could leverage commercial S&T. Sponsors of the study were Dr. James DeCorpo, DON Chief Technology Officer, Captain Dennis Ryan, Commanding Officer of the ONRIFO and Professor William Weldon, Technical Director ONRIFO.

The derived tasks for the study are given above. It is noteworthy that the tasks focus on European commercial companies.

The complete Terms of Reference are found in Appendix C.

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Panel Membership

Chairperson

Mr. Thomas Brancati

California Preferred Provider Group, Inc.

Vice Chairperson

Mr. M. A. Cramer*

Private Consultant

Panel Members

Dr. Philip W. Cheney*

Raytheon Company

Ms. Katherine C. Hegmann

Lockheed Martin Undersea Systems

Mr. C. L. "Neil" Hensel

Private Consultant

RADM S. J. Hostettler, USN (Ret.)*

Private Consultant

Dr. F. Michael Pestorius

The University of Texas at Austin

Dr. John C. Rich

Raytheon Company

Dr. Jerome A. Smith

Private Consultant

Mr. Myron "Mike" Sponder

Office of Naval Research

Mr. Kenneth "Ken" Swimm

Private Consultant

Panel Sponsors

Dr. James J. DeCorpo

Chief Technology Officer, DON

CAPT Dennis Ryan, III, USN

Office of Naval Research International Field Office

Professor William F. Weldon

Office of Naval Research International Field Office

ONRIFO Support

Dr. Hugh Casey

Mr. Michael Morgan

*Partial attendance

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Panel Membership

The panel consisted of a group of individuals with backgrounds in industry, academia and the military.

The panel was chaired by Mr. Thomas Brancati. Mr. M.A. Cramer served as Vice Chair. Dr. Hugh Casey and Mr. Michael Morgan, ONRIFO provided support for the panel. The complete panel membership is shown in the chart above.

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List of Sites Visited

ABB	Helsinki, Finland
ALCATEL	Paris, France
ALSTOM	Rugby, England
Nokia	Helsinki, Finland
Siemens	Erlangen, Germany
Siemens	Munich, Germany
Rockwell Science Center	Thousand Oaks, CA
Lockheed Martin	Manassas, VA

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Sites Visited

The panel visited various European facilities and two US sites to gain a broad understanding of the complex issues involved in adopting commercial technology for DON use. Panel members visited European company sites in Finland, Germany, France and England, as well as US sites in Virginia and California.

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List of Briefings

Study Prospective	Professor Bill Weldon, ONRIFO Dr. Jim DeCorpo, DON CTO
Telecommunications	Siemens
Telecommunications	Nokia
Telecommunications	Alcatel
Power Electronics	ABB Marine
Power Electronics	Alstom
Power Electronics	Siemens
Power Electronics	Mr. Terry Ericson, ONR
Telecommunications	Dr. Neil Gerr, ONR
Power Electronics	Dr. Max Yoder, ONR
COTS Technology	Mr. Bob McCaig, Lockheed Martin
Open Systems	Mr. R. Varga, Boeing
Technology Planning & Acquisition	Mr. Miller Adams, Boeing

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List of Briefings

The panel received many briefs, including presentations on commercial research issues from multiple speakers at Siemens, Nokia, Alcatel, ABB and Alstom. To gain an additional perspective the panel heard briefings from the Office of Naval Research (ONR) as well as Lockheed Martin and Boeing. The panel also visited Lockheed Martin's Manassas facility to observe commercial off-the-shelf (COTS) insertion in undersea warfare systems. Although a visit to the Rockwell Science Center was made, no formal briefing was received. A question and answer session with Dr. John Viola took place at Rockwell.

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Why This Study is Appropriate Now

- Budgets are tight for both Development and Acquisition.
- Commercial sector investment dominates many technology areas.
- Commercial products can offer huge payoffs in performance/price.

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Why Study is Appropriate Now

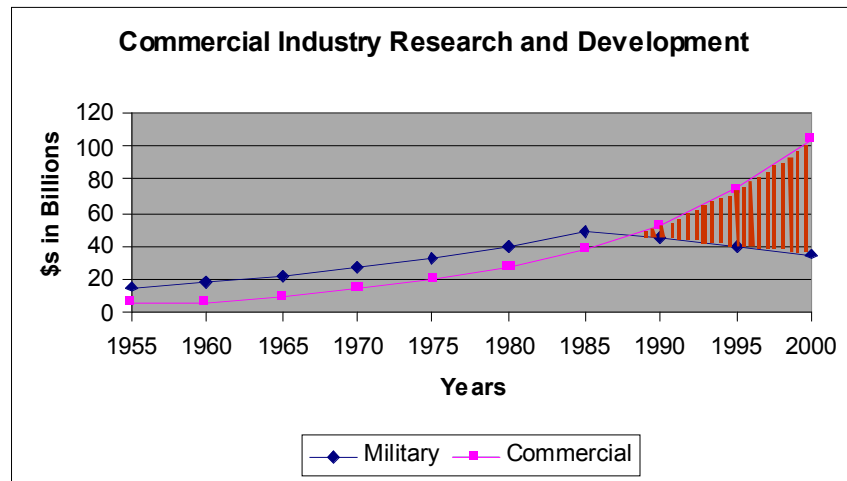
This study is particularly timely with the growing conflict between increasing requirements and decreasing budgets. Both the development and acquisition communities must find ways to fit their needs into lower budgets.

Commercial research, in many areas, far outstrips the Government's ability to invest. Thus, technology will be driven by economic reasons. The military, if it wants to keep up with certain technologies, must learn to adopt commercial products. These products, if taken as is, will provide huge monetary savings.

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Why the Transition to Commercial Technologies

Leverage the Commercial Marketplace



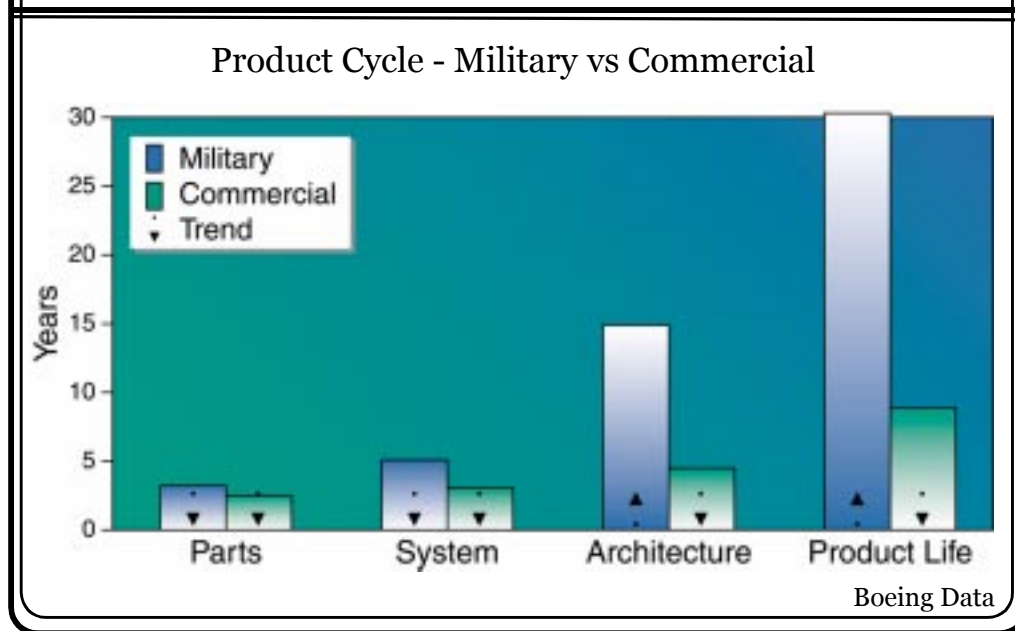
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Why the Transition to Commercial Technologies

The Department of Defense (DoD) invested \$15 billion in 1955 for R&D, with that number escalating by 4% per year until it peaked at about \$45 billion in the mid 1980's. It then declined to \$35 billion by 2000. On the other hand, commercial industry invested \$5 billion in 1955 with that number escalating at 7% per year throughout the timeframe to 2000 and is forecasted to continue for the foreseeable future. The significant investments made in commercial industry began to outstrip those done in the military in the 1980's. Prior to this time Government investments drove the technology content of US and world industry. The trend since that time has dramatically shifted to industrial investment. By the early 1990's industrial investment became significantly larger than that of the Government and trends are widening that estimate. This has resulted in significant improvements in commercial product performance and reductions in system life cycle cost. These data verify the need for the DON to rapidly move to incorporate commercial products and technology into our platforms.

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Technology Trends



Technology Trends

Understanding the application of commercial technology and products into a military environment requires understanding the development cycle and product life time differences in commercial and military industries. The system product life for military systems has classically been more than 30 years with many, e.g. B52 airplane, considerably longer. Commercial systems rarely last more than five to seven years. The trend is interesting in that the useful life cycle for military systems is lengthening and for commercial systems it is dramatically shortening. For architectures, the life cycle is forecasted to be about half as long, but the trends for military and commercial applications continue to go in opposite directions. Parts in both applications have relatively short one-to-three year life and in both applications product life is shortening. The implications for the military are that short commercial product lifetimes mean lack of support for obsolete parts and products. Movement to open system architectures enables the military to replace parts and systems with an end result of improved product performance at much lower lifetime cost.

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Study Methodology

- Choose two technology areas critical to DON needs and where Europe is a leader.
 - Power Electronics
 - Wireless Telecommunications
- Perform assessment of these selected technology areas.
 - Understand investment strategy for the next two product cycles
 - Identify R&D collaboration opportunities
- Comment on DON's ability to understand, influence and better utilize these commercial technologies.
- Investigate processes for monitoring and utilizing COTS, used by systems integrators.

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Study Methodology

During the study it was decided to select two areas where Europe provides leadership in commercial technologies critical to the DON. After considerable iteration the power electronics and telecommunications areas were selected. Once this decision was made visits were scheduled to key industrial leaders in each technology area. The panel prepared a list of questions which were sent to the companies in advance (see Appendix A).

The panel received briefings from Lockheed Martin and Boeing on approaches used within industry to manage insertion of commercial products and technology into their systems and products.

The panel was divided into two groups which visited the selected companies in December 1999. The intent was to develop an understanding of the investment strategy for at least the next two product cycles and to identify any opportunities for S&T collaboration. The panel was tasked to determine enough information to comment on the DON's ability to understand and influence these commercial technology investment strategies.

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Why Focus on European Technology

- Commercial Technology is global
- Geographic concentration of technology
- ONRIFO support available
- Provides a foundation for study expansion in the US and Asia

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Why Focus on European Technology

Commercial technologies are increasingly global. One telecommunications company that the panel visited has 40 R&D centers in 12 different countries. In other cases, such as high power semiconductor devices and ceramics, the technology is led by a group of non-US companies. The panel felt that by examining two technology areas that are being led by European companies that we would: (1) highlight the global nature of commercial technology; (2) stimulate similar assessments of commercially led technologies in the US and Asia; and (3) generate a methodology that would be of use in other assessments.

Also, the task was made much more feasible by the expertise and connectivity of the ONRIFO in London.

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Take Away Messages

- Commercial Sector is willing to share technology data at a level that is useful for DON planning.
 - Ask the right people with the right people
 - Participate in standards bodies
- DON ability to influence commercial technology development is minimal, if at all.
 - The winning formula is setting the stage to “adopt not adapt.”
- ASN(RD&A) establish a mechanism to find, disseminate and manage the utilization of commercial technology.

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Take Away Messages

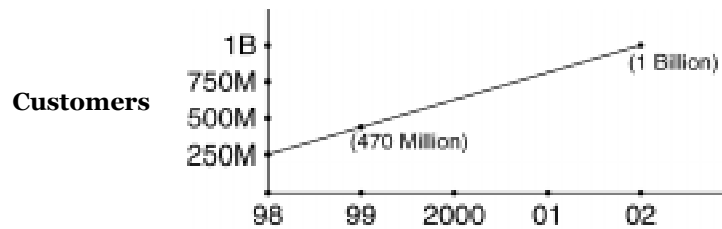
One of the critical issues involving use of commercial technology is the DON's ability to access technology. The panel found that the commercial sector has a comprehensive technology plan and a willingness to share it openly. However, the DON ability to influence technology is very industry dependent. In the telecommunications market, commercial users will drive OEM investments. By contrast, in the power electronics area companies are developing technology that complements DON research. As a result, the DON has some influence over technology developments in this market. In areas such as telecommunications, where the DON has little influence, the process needs to encourage use “as is” in those commercial products to obtain the cost savings and performance improvements, and avoid the urge to modify.

The DON needs to organize for success to reap the benefits of commercial technology. The panel found that many systems integration companies are already focused on incorporating COTS, and they have developed processes and organizations that provide useful models for the DON.

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Telecommunications Overview

- Market place 1999 ~ \$100 billion
 - 6 to 12 month handset product cycle
 - 3 to 5 year network infrastructure cycle
- Explosive growth



- 70% of world population has never made a telephone call
- Annual R&D 10% - 14% of revenue (\$10 billion in 1999)

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Telecommunications Overview

The wireless telecommunications industry has been doubling in revenue every year and in 1999 represented about a \$100 billion market. At present, 70% of the world's population has never made a phone call, and the customer base will continue to grow from 250 million in 1998 to over 1 billion in 2002.

As the commercial companies vie for this marketplace they are turning out new handset products every six to 12 months and new network infrastructure every three to five years. To support this growth significant investment is being made in R&D. Nokia, as an example, has over 13,000 people working in R&D. Typical areas include electronics, software, audio-visual processing, network architecture and wireless communications.

The Europeans have multi-lateral R&D projects, including many within the European Union's (EU) Framework Program, a joint program funded by the EU to push R&D as well as economic development.

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Telecommunications Overview (continued)

- Security/availability are critical commercial issues
- Worldwide military spectrum shrinking
- Europeans have unified view of Technology Roadmap
 - GSM (Global System for Mobile Communications)
 - UMTS (Universal Mobile Telecommunications System)
- Europeans have consolidated approach to standards
- Europeans have 60% of world market place
- US future is less clear
 - AMPS (Advanced Mobile Phone System)
 - TDMA (Time Division Multiple Access)
 - CDMA (Code Division Multiple Access)

DON needs to heed GSM and its successor standards
for interoperability and cost

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Telecommunications Overview

Both security and availability have been concerns of the military with respect to commercial products. Driven by the banking industry, significant progress in security has been made by the commercial R&D community. Improved availability based on hardware reliability and system architectures is also available.

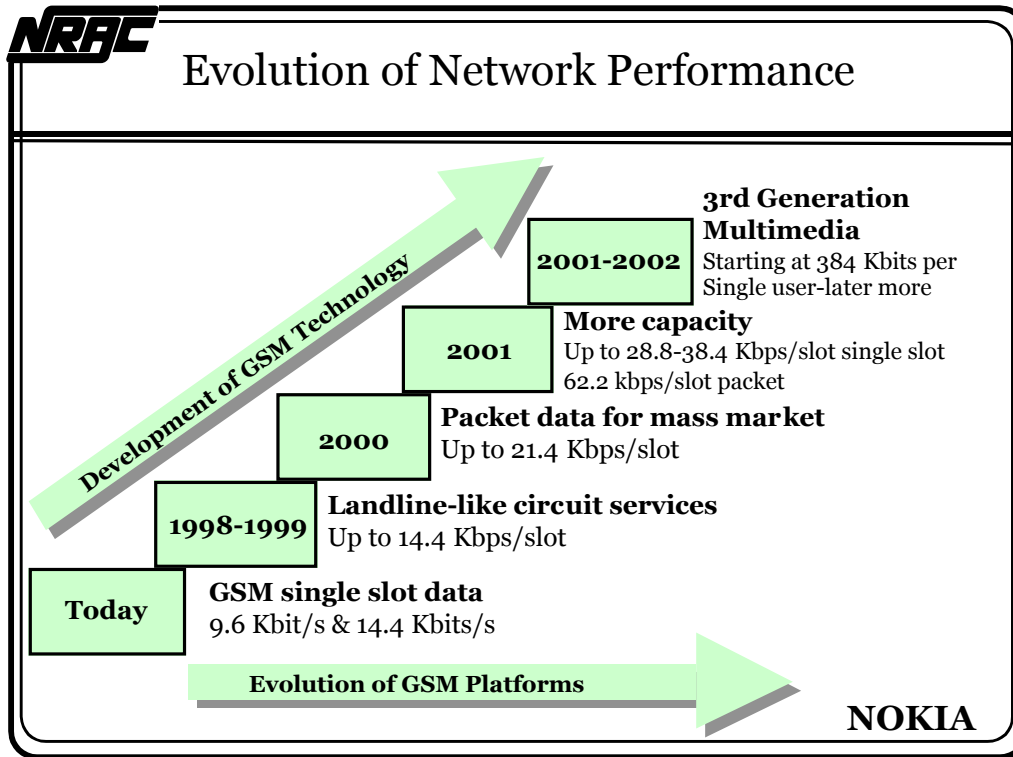
As the telecommunications bandwidth capabilities and customer base increase there will be continuing competition for spectrum. Some erosion of military bandwidth has already occurred and there will be continued pressure for further reductions.

The Europeans have, in general, adopted a unified approach to mobile communications. They have standardized on GSM (Global System for Mobile Communications) and the views of the visited companies (Nokia, Siemens, Alcatel) with respect to the future standards growth were remarkably similar. They expect to grow to a UMTS (Universal Mobile Telephone System) standard (384 Kbps to 155 Mbps) in the 2002-to-2010 time frame. GSM represents 60% of the world market, and there are indications that the GSM standards will also be adopted by the growing Asian market. The Asian Cellular Satellite System under construction for Indonesia, the Philippines, and Malaysia has adopted GSM and should be servicing that area by 2002. The Chinese have not made a

final decision as of yet, but are developing standards that are compatible with GSM.

The US has a more fragmented approach with DAMPS (Digital Advanced Mobil Phone Service) as the standard, that represents only 9% of the world market place. CDMA (Code Division Multiple Access) has 15% of the market and AMPS (advanced [analog] mobile phone system) is 16%.

The magnitude of commercial investment in this area and the predominant acceptance of GSM and its successor standards, with the projected growth in bandwidth (384 Kbps in 2002 and 155 Mbps by 2010), points to the necessity for the DON to understand this commercial technology and take appropriate action in both its Research, Development and Acquisition planning.

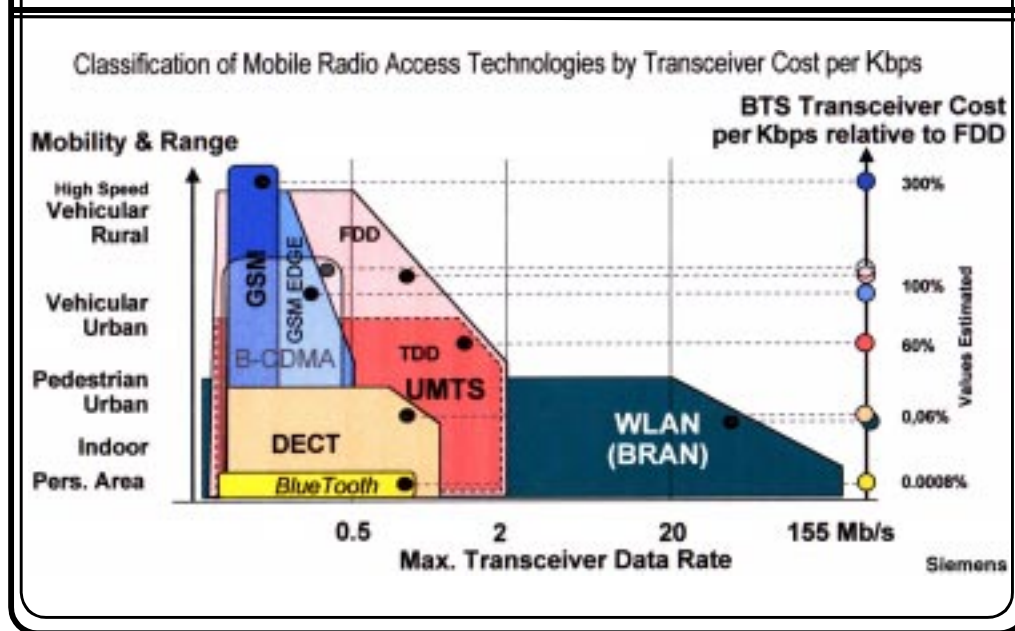


Evolution of Network Performance

The rapidly growing wireless telecommunications market is moving from a second-generation system to third and fourth generation technology insertion in three years or less. The technology (non-US) market is moving from analog to digital wireless in a very short period of time. The enhanced digital GSM technology change that will drive the market most significantly is the introduction of packet switching and wide band communications (~384 Kbps/single user) planned as early as 2002. This will enable wireless integration with the internet and introduction of significant data communications over and above that of voice. Initial data services on wireless phones were introduced in 1999. Combining different competencies in audio-visual signal processing will develop multimedia system solutions. Compression coding and data encryption schemes to provide network security lie at the heart of digital audiovisual transmission. Efficient use of scarce radio spectrum has transitioned single slot to Transmission Control Protocol/Internet Protocol (TCP/IP) packet switched communications to supply high-speed data at dramatic cost efficiencies. Fourth generation technology changes for stationary users are forecasted, in the five-to-ten year cycle, to introduce broadband multipath radio channel with data rates up to 155 Mbps. Integration of different systems including wireless local area network (LAN) leading to multiple air interfaces within one seamless network is forecasted to be driving the market by 2010.

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Radio Access Technologies Comparison



Radio Access Technologies Comparison

The chart above shows an interesting comparison of base station transceiver technologies. It shows the theoretical envelope of data rate as a function of wireless telephone user velocity. Velocities vary from zero, a stationary user, to ~300 kilometers/hour, a user in a high-speed train. Data rates vary from zero to 155 megabits/second. Today's wireless phone rate is 9.6 kilobits/second.

One can see how the envelopes expand as we migrate from present technology (GSM), to next year's technology (GSM-EDGE), to third generation technology (UMTS). The prior chart indicated bit rates that the users can expect in each year. These rates are much lower than the theoretical maximum shown at the right hand edge of each of these envelopes, indicating users can expect improvements in data rate in each of these technologies.

This chart also shows the clear difference in cost associated with providing service to the mobile user. In addition we see that the cost for increasing data rates is forecast to decrease in each new generation, making the cost per bit decline rapidly.

The important messages to take away from this and the previous chart are:

- A roadmap for digital wireless communication exists in Europe

- Following this roadmap leads to data rates for mobile users in a few years that greatly exceed today's direct subscriber line rates for stationary users
- Costs per bit are projected to decrease dramatically

Sites Visited

- Siemens -- Munich, Germany
 - '99 Sales \$5B R&D \$.5B
 - Future profits: services, applications, and content
- Nokia -- Helsinki, Finland
 - '99 Sales \$21B R&D \$2B
 - Focus on terminal and base station hardware
- Alcatel -- Paris, France
 - '99 Sales \$22.5B R&D \$2.5B
 - Technology focus on infrastructure

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Sites Visited

Three European companies in the wireless telecommunications industry were visited. They represent, in aggregate, \$48 billion annual sales, approximately one third of the worldwide sales in 1999.

Siemens had \$5 billion in sales in their telecommunications business in 1999 with R&D expenditures, including product development, of approximately \$500 million. This company is restructuring its business, selling off component manufacturing divisions, acquiring key technology businesses, and establishing production joint ventures. They have been a major producer of infrastructure hardware (switches, base station transceivers) and want to become a major producer of handset hardware. However, as these hardware items become commodities, they believe profitability will derive more from services, application software, and content.

Nokia had ~\$21 billion in 1999 sales, virtually all from telecommunications, and their R&D investment exceeded \$2 billion. Ten years ago only 5% of their revenue derived from telecommunications. They are focused on producing handsets, 60% of current sales, and base station, 33% of current sales, hardware. They employ 54,000 people, and they have 40 R&D centers, located in 12 countries. Their view of the technology evolution is very consistent with Siemens. Both companies believe the developing nations in Asia are moving toward a GSM and its derivative standards, and they have to maintain separate products and technology efforts for the US market.

Alcatel had 1999 sales of \$22.5 billion in their telecommunications business, approximately 90% of total sales. Their technology efforts are focused on infrastructure systems. They have core competencies in high-speed copper transmission technologies such as asynchronous data subscriber line (ADSL) and video data subscriber line (VDSL), intelligent networks, and transceivers for wireless base stations.

Opportunities for Collaboration

- Significant Areas of European R&D are of interest to DON
 - Network architectures
 - Converged Voice-Data Networks
 - Radio access technologies
 - RF ASICs, etc.
- Europeans driven by their business plan
- Focused on 3rd generation and up
- DON needs to participate in international standards committees

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Opportunities for Collaboration

The panel found a very direct relationship between the corporate business/marketing plan and the technology investments strategy. All of the companies have multiple collaborations within government, university and corporate entities. The originator of R&D within each corporation falls into either centralized or decentralized approaches. Both are principally driven by the business units/market place. Longer term (5 to 10 years) technology is often done in collaboration with competitors. Several of the companies were jointly involved in the European Union's Framework program. All companies appeared open to some level of technical collaboration with the DON, but no specific opportunities surfaced. It is important to note that opportunity for interface does exist through participation bodies.

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Telecommunications Summary

- For interoperability, performance and cost reasons the DON must stay abreast of, and appropriately take advantage of the commercial telecommunications technology revolution.
 - By 2002, 384 Kbps wireless data rates will be available at very low cost. [155 Mbps in 2010]
- Telecommunications technology is global and US as well as international capability need to be assessed.
 - Major European companies are willing to share their view of the future.
 - DON should participate in international standards committees which drive the future.
 - Customers as well as producers provide key insight into future capabilities.

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Telecommunications Summary

The magnitude of the “information age” revolution is driving the wireless telecommunications marketplace. This market will continue to grow rapidly, improving bandwidth and reducing product costs, for at least the next decade. With the European community focused and united around the GSM standard and its successors, the DON needs to remain abreast of the interoperability issues this may precipitate and determine the appropriate telecommunications policy.

By 2002 the expected mobile wireless bandwidth will be 384 Kbps with potential long-term growth to 155 Mbps. Even this near term commercial capability can satisfy some DON requirements at very low cost. The availability of this capability should be factored into DON acquisition planning.

Wireless telecommunications technology and products are being developed globally, and US and Asian contributors should be evaluated, in addition to those in Europe. All the European companies contacted were willing to provide adequate information at the level required for the DON to make informed decisions about adopting future technology and product developments.

It also became apparent that the standards committees have a significant impact on this market. Participation on standards committees or, at least, understanding the projected outcomes of various options for standards would be valuable.

The panel realized after its site visits that it had not verified either the rates of implementation or the stated commercial requirements driving the development of new products. The producers are planning to implement 384 Kbps, Internet protocol compatible equipment in 2002. It would be useful to know if the base station operators are planning the capital equipment investments necessary to make this happen. Furthermore, the expansion of bandwidth is all driven by the producer's perception that wireless phone users want Internet connectivity. It would be valuable to have independent verification. The important point is that the DON must assess not only suppliers but also other customers in its evaluation of commercial products and technologies.

Sites Visited

- Siemens A&D -- Erlangen, Germany
 - Power electronics \$7 Billion/yr
 - Most diverse and complete electrical standard products company in world
- ABB Marine -- Helsinki, Finland
 - Podded Propulsor Sales: \$100 Million/yr
 - Azimuthing podded electrical ship drives
- ALSTOM -- Rugby, England
 - Power Electronics \$3.5 Billion/yr
 - Heavy electrical systems integration is core business; custom products strengths

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Sites Visited

Three European companies were visited. These companies, Siemens, ABB and ALSTOM, are the world leaders in power electronics and electric propulsion. The only US competitor is General Electric, a distant fourth. Their combined annual sales of ~ \$11 billion represent approximately one third of the total world market.

Siemens had \$70 billion in 1998 sales. They employ 460,000 people in 190 countries, and annual R&D expenditures are approximately 10%. Their A&D (Automation and Drives) division which hosted us has 53,000 employees, \$7 billion in annual sales, and R&D expenditures of about \$700 million. Their product line includes variable speed drives, switches, relays, contactors, AC & DC motors and generators, converters, inverters, and other components. Design and development are concentrated in Germany; product manufacturing is located in the country of use.

The Asea Brown Boveri (ABB) visit was to their Marine Division, and the response to our inquiries was focused on their podded propulsor work, which is applied extensively in cruise liners, transfer tankers and some icebreakers. ABB builds variable speed drives, power generation and distribution systems, integrated machine automation systems, and AC & DC motors. Some of the motor and generator components are very large.

ALSTOM is a company formed from the merger of several smaller organizations; Thompson, GEC, GE UK, GE France, and several others.

ALSTOM's most recent total revenue figure (98/99) is \$21 billion. Twenty-one percent of their business is in the US. Their R&D budget in 1998/1999 was \$515 million. ALSTOM sees itself as more flexible and innovative than ABB or Siemens. They are willing to take on one of-a-kind special applications.

Power Electronics Overview

- Low volume/high unit cost/capital intensive business
- Long component life (~ 30 years)/harsh operational environment/stringent reliability standards
- Heavy R&D investment ~ 10% of total revenue
- Market size ~ \$50 Billion/year
- Key Customers
 - Power Generation & Distribution
 - Nuclear, Fossil
 - Transportation
 - Rail, Ship
 - Heavy Industry
 - Metals, Paper, Chemical

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Power Electronics Overview

The power electronics industry is characterized by low product volume and high unit cost. It is capital intensive, requiring heavy machinery and elaborate processes.

Technology development and product improvement are part of this industry and heavy R&D investment, on the order of 10% of revenue is typical. The products are characteristically long lived (~ 30 years) with expectations and histories of robustness and reliability in typically harsh operating environments. This global market of some \$50 billion per year includes rail transportation, power and heavy industry, as well as ship drives.

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European Dominance -- Navy Relevance

- Percent of world market in power generation and conditioning, large drives and motors.
 - Siemens 14%
 - ABB 12%
 - Alstom 7%
 - GE 6%
 - Others (< 5% each) 61%
- Strong corporate interest in COTS for ship power distribution and propulsion.
- Top three have world dominance in electrical propulsion on board ships.

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European Dominance -- Navy Relevance

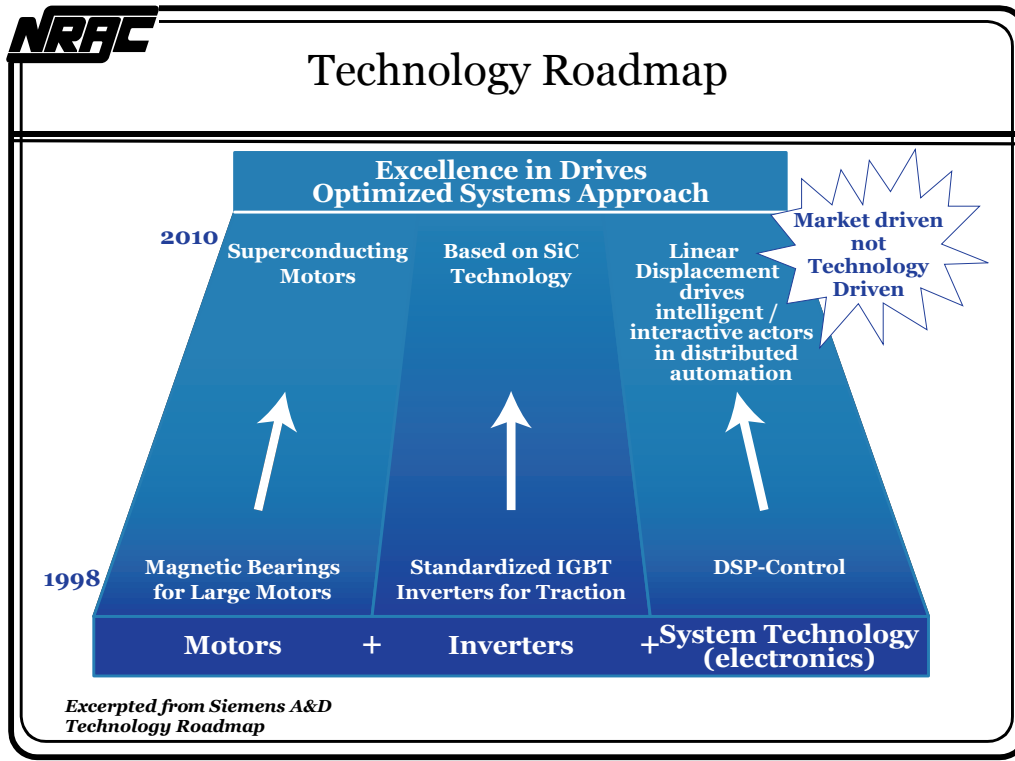
The global market for power generation equipment and large drives and motors is dominated by Europeans, mainly Siemens, ABB and ALSTOM. This industrial sector was for most of its life dominated by US companies. Sales volumes, domestic political consideration, and higher European oil prices are all factors in the emergence of European leadership in this sector. These European companies all value their global positions, and look to building sales and manufacturing in countries worldwide. They also are aggressive competitors among themselves at home and abroad.

Although possessing overseas manufacturing strategies, these companies maintain R&D and engineering in Europe. On the other hand, these companies appear to have a long range approach to general research in power electronics, having good university ties and, in fact, some European collaboration among themselves in so-called “pre-competitive” areas. While hardly a “Fortress Europe” strategy, there are obvious important geographic and European Union collaborative ties.

If the DON intends to utilize COTS power electronics components, the use of European products is inevitable.

At the electric ship propulsion product level, 90% of the propulsion systems are produced in Europe. Electric ship propulsion is growing world-wide and is of significant importance to DON developments.

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Technology Roadmap

Siemens presented an excellent technology roadmap extending out to 2010 and illustrated their top down view of future developments across the power electronics spectrum. The points made included:

- Siemens buys new transistor devices from Eupec (part of Siemens), ABB and Toshiba (ABB also uses Toshiba semiconductor devices).
- Siemens is committed to product standardization for very diverse product applications.
- There is no end in sight to product change.
- Siemens drives the market and tries to anticipate customer needs. They don't wait for market demand.

Technology refresh planning is built into every product. In the near term (through 2000), Siemens expects only incremental improvements in device technology. Advances such as the introduction of wide band gap SiC based devices, high temperature superconductors and intelligent interactive controllers are ten years away. GaN devices are purely basic research activity.

Other conclusions regarding Siemen's strategy included:

- Siemens intends to dominate the large drives and power electronics sector.
- They expect their customers to use standard Siemens product line.
- They have minimal interest in building unique designs or in changing base designs to accommodate customer requirements.
- Siemens is committed to a robust internal and university R&D structure.

- They are well established in the US and view the US as a growth market.
- They are interested in working with the DON, but do not view them as different from other customers.



Opportunities for Collaboration

- Significant areas of European R&D are of interest to DON.
 - Near term (now-2005) -- Evolutionary upgrade of existing parts
 - Long term (2005-2010) -- Wide band gap semiconductors, (SiC) superconducting motors, etc.
 - Beyond 2010 -- GaN
- DON has significant interface on a technology level.
- At product level, ALSTOM indicated more interest than Siemens, but no specific opportunities surfaced.
- ABB is participating in the DON Power Electronic Building Block (PEBBS) effort.

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Opportunities for Collaboration

Siemens presented the most comprehensive product development strategy. This strategy was characterized by evolutionary refinement of existing products with the phased introduction of new components such as active and passive magnetic bearings, permanent magnet motors and wide band gap device based components in the longer term. Some technologies such as GaN devices were seen as too immature to appear on the current product insertion horizon. ABB and Alstom's development plans, while not articulated as clearly as Siemens', did not differ significantly from this general outline.

The panel was also impressed with the identification of "pre-competitive" R&D. In short, this phase is marked by overt cooperation among companies that are competitors in later development phases. Alstom, in particular, appeared to welcome this collaboration which seemed to be driven by European Union funding support for basic research. The message for the DON here is that collaboration on longer term R&D may be an easier place to gain entry into future developments. DON laboratories have working knowledge and technical interfaces with the European companies on several of the long-term technology areas.

The status of current electric drive train components in meeting more stringent DON shock and signature standards is an area of intense current interest. Alstom, in particular, appeared eager to work with the DON to resolve these issues. Other companies may not perceive the DON to be a large enough

customer to warrant the development of targeted product improvements. Innovative contractual approaches are probably needed in this area. The DON must encourage contractors to be creative in their use of the commercial technology in any contractual solicitations.

Power Electronics Summary

- European companies dominate the ship electric drive market.
- R&D driven by commercial market forces.
 - 5 - 10 year technology insertion cycle
- DON market is not large enough to drive the commercial market.
- Current converter/controller technology offers opportunity for early COTS adoption.
- Side Note: Propulsor shortfalls for DON use, e.g., shock, signature, need continued close attention.
 - Incentivize contractors for maximum use of commercial technology/product insertion

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Power Electronics Summary

Power electronics provides the basis for the next generations of electric generators, large drives and motors. This market is dominated by Europeans, mainly Siemens, ABB and Alstom, at the product level. Of particular interest to the DON is the ship electric drive market where 90% of the market is owned by these companies.

At the system level the insertion cycle for new technologies is relatively slow (5 - 10 years) due to the major capital investments, long system life cycles, and a lack of requirements push from their customers.

In some areas (superconduction, power transistors, etc.) significant ONR understanding and technical interfaces exist. But, the DON portion of the component and system market place is not large enough to drive the direction of commercial technology. Nevertheless there will be opportunities in the near term to incorporate COTS converter/controller technology into DON developments.

The electric propulsion selection for the DD 21 places additional emphasis on this product area. Shortfalls against DON shock and signature requirements in present products need continued attention. Given the state of the commercial propulsor designs, emphasis needs to be placed on maximizing the insertion of commercial components and technology.

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Findings Summary

- Commercial investment is significantly larger than that of the DON.
 - 10 to 14% of revenue is what commercial companies spend on R&D.
 - Commercial research investment outpaced military significantly this last decade.
- Commercial Sector is willing to share technology data at a level that is useful for DON planning.
- System integration companies are exploiting commercial technology.
 - Dedicated organizations reporting at high level
 - Open architectures are essential

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Findings

Commercial companies nominally spend from 10 to 14% of revenues on R&D, including product development. The commercial telecommunications industry alone spent more on R&D in 1999 than the DON. The magnitude of commercial R&D investment is significantly greater than that of DOD, and the disparity has been growing for decades. These facts argue strongly for a DON policy of exploiting commercial technology.

One significant finding of the panel, contrary to the perception held prior to the fact-finding visits, was that the major European corporations were very willing to share relevant information on their product and technology development strategies. In the two technology areas selected, the companies provided information on their third and fourth generation future improvements, performance projections, product cycle definitions, utilization profiles, etc.

The defense industries have begun to create specific organizations to monitor and exploit commercial technology. Boeing, as an example, is spending over \$100 million on Venture Capital Funding of commercial companies pursuing technologies of interest to them. Lockheed Martin has created a process for identifying and incorporating COTS products into submarine weapons systems control systems. They conduct a survey of commercial suppliers every three months to assess changes in expected future technology and products to update their COTS implementation strategy.

“Open” system architectures have been selected by these systems integrators to facilitate cost effective implementation as new products on short time cycles become available. These “open” systems use standards for interfaces, services and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes. An “open” system is characterized by:

- Well defined, widely used, preferably non-proprietary interface protocols
- Use of standards which are developed/adopted by recognized standards bodies or the commercial market place
- Definition of all aspects of system interfaces to facilitate new or additional systems capabilities for a wide range of applications
- Explicit provision for expansion or upgrading through the incorporation of additional or higher performance elements with minimal system impact.

Conclusions

- DON needs a centralized approach to understanding future technology availability.
 - Identify relevant technologies; periodically reassess.
 - Disseminate understanding of standards, development cycles, architectures ...
 - Include US/Asian/European companies.
- DON ability to adopt (use as is) commercial technology is industry dependent.
- Short commercial development cycles can be compatible with DON long term system life cycles.
 - Open architectures are essential
- Culture change needed in S&T and acquisition communities.

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Conclusions

The DON needs to develop a mechanism for collecting and understanding information on future commercial technology. Candidate commercial technologies must be continually reevaluated. A system of periodic reviews of relevant commercial technologies must be performed to ensure that alterations in development roadmaps, standards, commercial requirements, etc. are understood in a DON context and disseminated to appropriate users.

In commercial industry as in the military, R&D investments are managed differently in different companies. The DON must understand each company's approach to insure they are capitalizing on the investments being made by industry.

The DON's ability to influence technology development is strong in markets where the size of the commercial market is comparable to the military market. In markets where the commercial market size is much larger than the military, the DON needs to adopt technology and products without modification, versus adapting or customizing commercial products, in order to secure the potential implementation time and cost savings.

Open architectures are essential for effective incorporation of the rapid changes in technology and products. In briefings from aerospace companies that are employing COTS products in their systems, the point was made repeatedly

that an open architecture is essential to be able to incorporate improved performance products at a low cost.

By definition, in areas where the commercial sector dominates a market, the DON finds itself to be just one of several customers. It is important for the DON to have a dialog with representatives of other major customers to evaluate producers, to understand the commercial drivers for next generation products, and to validate the pace of implementation of these future products.

The DON must make a culture change (maximize use of open architecture) in its R&D and acquisition communities and on the defense industry which supports it if they are to capitalize on the tremendous amount of commercial R&D investment.

Recommendation

- ASN(RD&A) must drive adoption of commercial systems.
 - Incentivize DON R&D and acquisition management to utilize commercial technology
 - Eliminate internal R&D where redundant with commercial
 - Chief Technology Officer logical focal point for management
 - Lean organization to establish, manage and distribute COTS knowledge base [<50 people]
 - Technology managers not Technologists
 - Personally connect with decision makers
 - Create a formal assessment methodology
 - Establish a process to monitor and report on commercial technology insertion success

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Recommendation

If DON is to achieve the potential performance improvements and cost reductions, a culture change in both acquisition and technology communities is necessary. R&D and acquisition managers must be incentivized to employ commercial technology and products. In a few examples the panel saw in the aerospace industry, success came from high level management direction to use commercial technology and effective dissemination of knowledge about commercial products and technology.

It is recommended that the CTO establish an organization tasked to create a formal assessment methodology and focus the interface with commercial industry. The panel has outlined the essential elements of the assessment methodology in Appendix B. This organization must be made up of technology managers that will directly interface with acquisition and S&T decision makers. Industry has had success establishing a technology champion from R&D or program management to integrate commercial technology into products and systems. A process must also be created to monitor and report on the success of commercial technology insertion in DON systems and platforms.

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Appendix A

Questions to Commercial Companies

- What is your principal market?
- What are the threats to your commercial position; i.e. standards, competitors, other technology?
- What drives your company's science and technology investment strategy?
- How often do you make or review science and technology investment decisions?
- What factors cause you to deviate from your science and technology investment strategy?
- Do you have strategic partners in your science and technology investment strategy?
- How do industry standards affect your strategy in science and technology?
- How do regulations affect your strategy in science and technology?
- What are your company's key or core technologies?
- How often does your technology change so significantly that it might be considered a "new generation" of technology?
- What changes do you foresee over the next two generations of technology?
- Do you look beyond two generations?
- Where do you plan to get your future technologies?
- Do you publish future technology documents?
- Do you have a program that collaborates with universities?
- How does your company view the lesson of Iridium? (telecommunications only)
- How do you feel about establishing a communication link with the US Navy so the possibility of future use of your products is enhanced?

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Appendix B

Assessment Methodology



Elements of Methodology

- Identify product lines/technologies of interest to DON that are led by commercial sector.
- Understand those product line/technologies with respect to DON requirements.
- Determine future commercial product stability and development strategy.
- Incorporate into DON investment strategy.

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Elements of Methodology

The key elements of the methodology recommended by this panel are shown above. Of course the process must start with the selection of commercially led technologies that are pertinent to the DON. An understanding of the commercial products, their projected evolution and marketplace drivers is essential. Also, the DON must assess whether these commercial products meet its requirements. It is also important to assess whether the supply of those products is assured for the foreseeable future. Finally, the DON must tailor its R&D and acquisition investments to be consistent with the conclusions of its assessment of these commercially-led technologies.

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Understand Product Line Characteristics

- What are the time scales?
 - development cycles
 - product life cycles
- What are the commercial requirements?
 - product performance
 - potential new applications, etc.
- Who are the key commercial players?
 - owns resources
- Evaluate risk factors
 - meeting DON requirements
 - supplier stability
 - customer intelligence

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Understand Product Line Characteristics

The panel discovered wide variances in both product development and life cycles. Wireless telephones may have a product development time of two years and a product life of one year. Other systems have a product life of up to 30 years. With short life products it is often cost effective to discard and replace rather than support obsolete products. The DON needs to understand the commercial requirements, which affect both product performance and cost. For example, commercial requirements for security and privacy may well meet DON requirements as they become driven by the banking industry.

The DON needs to understand the risk factors associated with incorporating commercial products. The DON needs to closely follow market trends and changes in standards and regulations which can influence the success or failure of product introductions. Breakthroughs in alternative technology often influence commercial product lines. As an example, the wireless/internet connection will dramatically change the personal computer market.

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Investment Strategy

- Incorporate into DON investment strategy.
 - Disseminate information to S&T and acquisition communities.
 - Ensure commercial technology advances are understood by DON R&D decision-makers.
 - Eliminate redundant investment.
 - Exploit commercial lower costs and superior performance, where it exists.
 - Monitor and report on commercial technology insertion success.

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Ultimately, exploitation of the commercial technology that has been identified and analyzed can only be accomplished if the DON investment strategy is changed to accept it. Knowledge of the commercial technology should be disseminated to both the R&D and the Acquisition communities within the DON. This body of information includes the identification of the companies leading the technology, the commercial applications driving the market, the strategies they are employing to grow their business, the technology roadmap they are following, and the technical and business challenges ahead.

Knowledge of the technology path is a necessary item, but changing the allocation of resources in the acquisition is essential to capitalizing on the benefits of commercial technology. Redundant DON funded R&D efforts have to be terminated. Acquisition programs need to apply people and dollars to both follow commercial developments and plan for its insertion in existing or new systems.

Lastly, any change in culture requires constant awareness of the progress being made. The DON must publicize and reward the successes in the implementation of commercial technology.

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Appendix C

Terms of Reference

Naval Research Advisory Committee (NRAC)

Commercial Science and Technology Panel

Background: In the current environment of severely limited budgets for Department of the Navy (DON) science and technology (S&T), it is essential to recognize, understand and take maximum advantage of other, complementary or supplementary, S&T investments. Foremost among these are the investments made in science and (mostly) technology by the commercial sector of industry. Although generally useful in planning DON S&T investment strategy, knowledge of commercial sector S&T strategy is particularly critical in areas where DON has chosen to rely on commercial, off-the-shelf technologies (COTs).

If DON COTs strategy is to be successful over the long term, it is important to:

1. thoroughly understand the relevant commercial S&T investment strategies in order to be able to anticipate the most likely future course of COTs; and
2. identify opportunities to influence, where possible and appropriate, the course of commercial S&T in order to insure its continued relevance to DON needs.

Failure to do this may result in DON finding future COTs unsuitable for its needs without time and resources to develop satisfactory alternatives.

The Office of Naval Research International Field Office (ONRIFO) has selected Commercial S&T as a focus for its European office.

Specific Tasking: The NRAC Panel on Commercial Science and Technology is constituted to advise the Commanding Officer and Technical Director of ONRIFO in the pursuit of an improved understanding of European commercial S&T investment strategy in areas related to DON dependence upon COTs.

1. Identify appropriate commercial industrial sectors, relevant to DON COTs reliance, where European industries play significant international roles. Computer, telecommunication and environmental sensor technologies are suggested as examples.
2. Establish an in-depth understanding of the intermediate-to-long-term S&T investment strategy of the industrial sectors identified in (1) above. (This is anticipated to require one or more European visits and could take advantage of ONRIFO's existing International Science Lecture Series contract with the National Research Council to invite appropriate National Academy of Engineering and/or National Academy of Science members to participate in the visits.)
3. Identify mutually beneficial opportunities for DON S&T collaboration in the commercial industrial sectors reviewed.

Sponsors:

Captain Dennis Ryan, USN, Commanding Officer ONRIFO

Professor William Weldon, Technical Director ONRIFO

Dr. James DeCorpo, Department of the Navy Chief Technology Officer

Appendix D

Acronyms

A&D	Automation and Drives
ABB	Asea, Brown, Boveri, Ltd.
AC	Alternating Current
ADSL	Asymmetric DSL
AMPS	Advanced (Analog) Mobile Phone Service
ASN(RD&A)	Assistant Secretary of the Navy (Research, Development and Acquisition)
B-CDMA	Broadband CDMA
BRAN	Broadband Radio Access Networks
BTS	Base Transceiver System
CDMA	Code Division Multiple Access
COTS	Commercial off-the-shelf
CTO	Chief Technology Officer
DAMPS	Digital Advanced Mobile Phone Service
DC	Direct Current
DECT	Digital Enhanced Cordless Telecommunications
DoD	Department of Defense
DON	Department of the Navy
DSL	Digital Subscriber Line
DSP	Digital Signal Processor
EDGE	Enhanced Data for GSM Evolution
EU	European Union
FDD	Frequency Division Duplex
GaN	Gallium Nitride
GE	General Electric
GEC	General Electric Canada
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IGBT	Insulated Gate Bipolar Transistor
Kbps	Kilobits per second

LAN	Local Area Network
Mbps	Megabits per second
NRAC	Naval Research Advisory Committee
OEM	Original Equipment Manufacturer
ONR	Office of Naval Research
ONRIFO	Office of Naval Research International Field Office
PEBBS	Power Electronic Building Blocks
R&D	Research and Development
RF ASICs	Radio Frequency Application-Specific Integrated Circuits
S&T	Science and Technology
SiC	Silicon Carbide
TCP/IP	Transmission Control Protocol/Internet Protocol
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
VDSL	Video Data Subscriber Line
WAP	Wireless Application Protocol
WLAN	Wireless Local Area Network